Climatic variables (temperature, precipitation, wind) influence marine production and species use as well as terrestrial disturbances such as flood, drought, fire, and landslides. Terrestrial disturbances are major factors affecting the interaction of water, sediment, and vegetation in salmon-bearing watersheds.

Human actions can strongly modify these natural cycles and disturbance regimes, and often exacerbate adverse consequences associated with them. Human actions also result in a host of additional problems, such as overfishing, migration blockages, introduction of non-native species, hatchery interactions, and reductions in the quantity and quality of physical habitat, water quality and flow.

Marine survival

Marine survival refers to the ability of fish to grow and survive in the ocean. Climatic cycles that govern temperatures of the North Pacific and Puget Sound profoundly affect the marine survival of local salmon production. Climate-driven variations in marine water temperature and ocean upwelling affect the availability of nutrients for production of plankton, which in turn affects food availability for salmonids. Changes in water temperatures also lead to changes in species composition, creating variability in the type and abundance of predators and competitors of salmon.

Marine cycles fluctuate between being favorable and adverse for chinook. Conditions have generally been unfavorable for local chinook salmon stocks since about the late 1970s. Qualitative information on water temperatures, nutrient availability, size of returning adults, and marine survival suggests that more favorable ocean conditions may be returning. However, it is too early to say this definitively or to estimate the degree to which the next cycle may potentially help chinook or anadromous salmon in general.

Harvest

Two major factors have caused many chinook populations to be excessively harvested in the past:

- Fisheries managers did not adequately take into account poor marine survival during the most recent cyclic downturns, and therefore did not cut back on permitted harvests at the intrastate (e.g. public vs. treaty), interstate (e.g. Alaska vs. Washington) or international (U.S. vs. Canada) levels.
- International (U.S. versus Canada) and interstate (e.g. Alaska versus Washington) political differences over harvest allocations created excessive harvests.

Only within the past decade or so has the cyclic nature of marine productivity and its implications for harvest management been well appreciated by harvest managers. In recent years, fisheries of Puget Sound chinook stocks have been severely curtailed in recognition of this factor. However, significant indirect harvests can still occur as a result of incidental catch in inter-

national, Alaskan and Puget Sound fisheries targeting other species, or in fisheries directed toward healthier chinook stocks (e.g. certain hatchery stocks such as Green River chinook and Puget Sound's "blackmouth" fishery for immature chinook salmon of hatchery origin).

In addition to reducing the sheer number of spawning fish, excessive harvest has had a variety of other potentially adverse effects, including reductions in adult body size and fecundity, in a diversity of salmon of different ages, and in nutrients derived from carcasses after spawning.

Modification of Disturbance Regimes

The rate and extent of natural disturbances (i.e. fire, floods, drought, landslides) have been profoundly altered by human activities.

Forest fires have been suppressed, leading to reductions in forest health and often leading to excessive impacts when fires inevitably occur.

Flooding rates have been altered by the loss of hydrologically mature forest cover; increases in impervious surfaces; and operation of dams for hydroelectric, flood control, and municipal water needs, leading to excessive or, in some cases, inadequate flows for formation of side channels and flushing flows for cleansing and transport of spawning gravel.

Sediment delivery to stream networks, estuaries, and marine beaches by landslides and bank erosion has been altered, resulting in changes in the substrate conditions (in other words, resulting in excessive amounts of fine sediment or coarsening of streambed or beach substrates).

Water, sediment, and vegetation interactions have been modified at landscape scales (in other words, over large areas), leading to inadequate amounts of large woody debris, reduction in quantity and quality of spawning and food producing substrates, and loss of high quality habitats. Disturbance regime shifts ultimately may favor certain, less-desirable species (e.g., cutthroat in urban streams that were believed to have been historically coho dominated). Or, if the species is unable to adapt, such shifts may effectively extirpate the use of some habitats by certain species altogether (e.g., chinook use of small- to moderate-sized urban streams that historically would have had made small, but significant contributions to chinook productivity).

Barriers

Migration of juvenile and adult salmon can be affected by easily identifiable structures, such as undersized or improperly placed culverts (which also alter the flow of sediment and large woody debris), lockage facilities (i.e., Ballard Locks), and fish weirs. Migrations also are affected by less-obvious water quality and quantity problems (low dissolved oxygen, high-water temperatures, inadequate flows) that cause fish to alter their migration routes or delay their migration timing.

In some instances, structures placed for broodstock collection for hatchery operations either block or modify stream reach selection of returning adult salmon, potentially causing fish to spawn in less desirable habitats.

Physical Habitat Quantity and Quality

Water, sediment, and vegetation combine to create the physical habitat (e.g. pools and riffles, side channels, estuarine sloughs, and marine beaches) to which salmon are adapted. The interaction of these variables are adversely affected by numerous activities conducted to varying degrees throughout developing areas of King County and Puget Sound.

These include activities include channelization and bank hardening, floodplain development, removal of large woody debris, removal and modification of riparian forests, flow regulation, water withdrawals, dredging, commercial gravel removal, and construction of piers, docks, and bulkheads.

The result is a reduction of quantity and quality of available physical habitat, including spawning gravel, juvenile rearing habitat, smolt out-migration pathways (including lower ends of rivers, estuaries, and near-shore marine areas), and adult migration, holding and spawning conditions.

Water Quality

Poor water quality affects the suitability of habitat for chinook regardless of its structural suitability. Low dissolved oxygen, high temperature, and excessive turbidity and fine sediment are the primary factors degrading water quality. High pre-spawn mortality of adult chinook holding in the Sammamish River prior to entering Bear and Issaquah creeks has been attributed to high temperature. Conversely, the upper reaches of Cottage Lake Creek, a tributary to Bear Creek, had some of the highest densities of spawning chinook observed in the Lake Washington watershed, presumably due to contributions of high quality cold water springs.

Many other pollutants, including heavy metals and a wide array inorganic and organic compounds used as pesticides, herbicides, fungicides, fertilizers, cleaning agents, fuels and lubricants, typically are found in urban and agricultural areas and contribute to the degradation of water quality. The effects of these pollutants on the physiology, reproductive behavior and long-term survival of salmon in King County is not well understood.

Flow Modifications

Water flow modification due to flood control regulation, water diversions (permitted and unpermitted), and land development, affect the majority of King County's chinook-bearing streams.

Four major dams in King County (South Fork Tolt, Masonry, Howard Hanson, and Mud Mountain) modify flows in the Tolt, Cedar, Green, and White rivers, respectively. The relative effect of these dams on flows needed for fish and habitat ranges from high on the Green, where the natural flood regime has been heavily modified, to relatively low for the Tolt, where instream flow agreements have been set to minimize downstream impacts. The effect of water diversion and flow regulation on Cedar River chinook (about 27% of mean annual flow of the river is removed for municipal use) is not currently well known.

In addition to the major diversions, numerous smaller withdrawals for municipal, residential and agricultural use occur throughout the county. The most significant of these smaller diversions is in the Cedar River, where about 75% of late-summer, early-fall baseflows are taken out of Rock Creek (WRIA # 08.0338) for municipal use. Rock Creek is an extremely high-quality habitat with significant historic chinook use prior to diversions.

Loss of hydrologically mature forest cover, due to urban development or excessive timber harvest particularly at elevations susceptible to rain-on-snow events, can result in significant modifications to stormflows and baseflows.

Hatchery Interactions

Native chinook are potentially impacted by hatchery fish or by hatchery operations in a variety of ways, including: interceptions in mixed-stock fisheries; competition with hatchery chinook; predation by hatchery-reared coho, steelhead, and rainbow and cutthroat trout; blockage of adult migration during broodstock collection; and transmission of disease.

Species Interactions

As with any wild animal, native chinook must survive in an environment where there is both *intraspecific* (i.e., within the same species) and *interspecific* (i.e., among other species) competition for limited resources and where a host of predators will eat them. Both native species (to which chinook are adapted and presumably compatible) and non-native species (to which chinook did not adapt and may not be compatible) exist in King County waters.

Habitat changes that reduce cover or food or that create physiological stress, such as high temperature and low dissolved oxygen, have the potential to favor chinook competitors and predators. When degraded, improvements in habitat are important to enhance chinook survival in the face of rigorous competition and predation.

Among the more potentially adverse species interactions in King County, is the predation of chinook by non-native bass, perch, and bream that have become established in Lake Washington. In Puget Sound and in coastal waters, adverse species interactions may include competition with delayed-release chinook stocked in Puget Sound to create blackmouth fisheries and marine predation by mackerel and hake whose predation effects are likely enhanced during periods of warmer ocean temperatures. Although often cited, it is not clear that marine mammal predation is a major factor in the decline of chinook salmon.